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14. ABSTRACT
To coherently control molecular collisions using a superposition of molecular quantum states, part of the DURIP equipment money was utilized to fabricate a high vacuum molecular beam reaction chamber. To obtain high resolution angular distributions, the reaction chamber has been designed with a velocity map imaging facility. The velocity map imaging comprises a couple of ion lenses, a flight tube and a high-resolution position sensitive RoentDek delay line detector. Another part of the DURIP equipment money was also utilized to acquire an

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Report Title

Final Report: Preparation of Phase-Locked Molecular Quantum States

ABSTRACT

To coherently control molecular collisions using a superposition of molecular quantum states, part of the DURIP equipment money was utilized to fabricate a high vacuum molecular beam reaction chamber. To obtain high resolution angular distributions, the reaction chamber has been designed with a velocity map imaging facility. The velocity map imaging comprises a couple of ion lenses, a flight tube and a high-resolution position sensitive RoentDek delay line detector. Another part of the DURIP equipment money was also utilized to acquire an injection-locked Q-switched Nd^{+3}:YAG laser which provides both the nanosecond single-mode pump for the Stark induced adiabatic Raman passage (SARP) as well as the pump for the single-mode pulsed dye laser amplifier. Using this equipment we are now ready to demonstrate for the first time quantum interference in a single molecular collision.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received		Paper
12/04/2014	1.00	Nandini Mukherjee, Wenrui Dong, Richard N. Zare. Coherent superposition of M-states in a single rovibrational level of H2 by Stark-induced adiabatic Raman passage, The Journal of Chemical Physics, (02 2014): 74201. doi: 10.1063/1.4865131
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Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received	Paper
TOTAL:	

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Names of Under Graduate students supported

NAME PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00
The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:...... 0.00
The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:...... 0.00
Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):...... 0.00
Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:...... 0.00
The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00
The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:...... 0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Preparation of Phase-Locked Molecular Quantum States

To understand a collision process (D+H2?HD+H) at the quantum level our goal is to experimentally study the scattering dynamics by preparing the target molecule (H2) in an addressable single or a coherent superposition of quantum states. To prepare a target molecule in a desired rovibrational M-quantum state within the ground electronic surface we introduced a new coherent optical technique called Stark induced adiabatic Raman passage (SARP). We have demonstrated SARP successfully transferring nearly the complete population of the ground H2(v=0, J=0) molecule to a vibrationally excited H2(v=1, J=0,2, M) state, thus reaching the first milestone of the proposed project. More recently, SARP has achieved the second important milestone by preparing a target H2 molecule in a coherent superposition of M-states within a single rovibrational (v=1, J=2) energy eigenstate thus, preparing where, the complex coefficients of superposition are controlled by mixing various polarizations of the pump and Stokes laser pulses.

To reach our final goal to control scattering processes using the coherent superposition of quantum states, part of the DURIP equipment money was utilized to fabricate a high vacuum molecular beam reaction chamber. This reaction chamber provides a highly collimated molecular beam, which is essential for preparing the collision partners in addressable quantum states with well-defined relative velocity. To obtain a high-resolution angular distribution (differential cross-section) we fabricated the reaction chamber that allows velocity map imaging of the scattered molecules, which are detected state selectively using resonance enhanced multiphoton ionization. The velocity map imaging has been made possible by designing a mass-spectrometer, which consists of ion lenses, a flight tube and a high-resolution position sensitive RoentDek delay line detector. A part of the DURIP equipment money was also utilized to acquire an injection-locked Q-switched Nd+3:YAG laser which provides both the nanosecond single-mode pump for the SARP excitation as well as the pump for the single-mode pulsed dye laser amplifier. Using the reaction chamber and the single-mode nanosecond tunable laser pulses we are now equipped to demonstrate for the first time quantum interference in molecular scattering, which is analogous to the Young's double slit experiment.
Our immediate goal is as follows:

1. Study inelastic three- and four-atom scattering dynamics using a SARP prepared target molecule in a single rovibrational M-state and compare experiment with theory.

2. Utilize SARP with appropriate pump and Stokes laser pulses to reach higher vibrational excited states of H2. By stretching the bond length our purpose is to explore regions of the reaction potential with possible curve crossings (conical intersection).

3. Demonstrate M-state interference in dynamical stereochemistry and retrieve the phase information of scattering amplitude.

Technology Transfer